(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(11) WO *00/75522* (13) A1

(21) PCT/JP00/03614

(22) 02 June 2000 (02.06.2000)

(25) Japanese (26) Japanese

(30) 11/158148 04 June 1999 (04.06.1999) JP

(43) 14 December 2000 (14.12.2000)

(51)[7] F16C 17/10, 17/22, 33/12, 33/14, C23C 8/32

(54) BEARING DEVICE AND METHOD OF MANUFACTURING THE BEARING DEVICE

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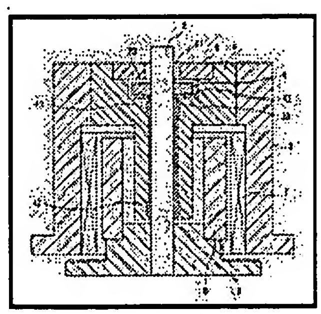
(81) JP, US

Published

— *with international search report*



(57) A bearing device having dynamic pressure bearing with less variation in bearing clearance according to a variation in service temperature and a corrosiveness and a sufficient hardness on the surface of a shaft, wherein a sleeve (4) is made of copper alloy, a solution-heat-treated austenitic stainless steel is used as the material of the shaft (1) and, after the stainless steel is machined in a shaft body, a carburization treatment is applied to the shaft body so as to form a carburized hard layer on the surface of the shaft, and then the shaft high in surface hardness and excellent in bearing surface roughness is used so as to increase the durability of the bearing device with dynamic pressure

bearing against starting and stopping, and also the coefficient of thermal expansion of the material forming the sleeve is reduced to below that of the material forming the shaft so as to improve the rigidity of the bearing at high temperatures.

CLAIMS

[Claim 1] In the bearing equipment which is equipped with a shaft and a sleeve, is made to produce dynamic pressure among both, and acquires a bearing operation When said shaft performs carburization processing to the stem which consists of austenitic stainless steel by which solution treatment was carried out, it is bearing equipment which a carburization hardening layer is formed in a front face, and is characterized by the surface hardness of the bearing surface of this shaft being 400 or more Hv(s).

[Claim 2] The surface roughness (Ra) of the bearing surface of said shaft is bearing equipment according to claim 1 which is 0.30 micrometers or less.

[Claim 3] The coefficient of thermal expansion of the ingredient which makes said sleeve is the bearing equipment [almost same similarly to the coefficient of thermal expansion of the austenitic stainless steel which forms a shaft] according to claim 1 or 2.

[Claim 4] Said sleeve is bearing equipment according to claim 3 which consists of a copper alloy.

[Claim 5] Said sleeve is bearing equipment according to claim 1 or 2 which consists of an ingredient with a coefficient of thermal expansion smaller than the austenitic stainless steel which forms a shaft.

[Claim 6] Said sleeve is bearing equipment according to claim 5 which consists of ferritic stainless steel or martensitic stainless steel.

[Claim 7] It is the manufacture approach of the bearing equipment indicated by any 1 term of claims 1-6. It is the manufacture approach of the bearing equipment characterized by performing said carburization processing at the temperature of 400-500 degrees C under a carburization gas ambient atmosphere,

and preparing a carburization hardening layer in the bearing surface of a shaft at least.

[Claim 8] Said carburization processing is the manufacture approach according to claim 7 performed under the ambient atmosphere of the mixed gas of RX gas and CO2 gas.

[Claim 9] Said carburization processing is the manufacture approach according to claim 7 performed under the ambient atmosphere of unsaturated hydrocarbon gas under a vacuum.

[Claim 10] The manufacture approach given in any 1 term of claims 7-9 which carry out the process which carries out heating maintenance to the temperature of 250-450 degrees C under a fluorine system gas ambient atmosphere before said carburization processing.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

Technical field This invention relates to a thing suitable as bearing equipment used for information machines and equipment, sound and image machine dexterity, and the spindle motor especially for a magnetic disk drive or optical disk units about bearing equipment (bearing equipment which is equipped with a shaft and a sleeve, is made to produce dynamic pressure among both, and acquires a bearing operation) equipped with the hydrodynamic bearing.

Background technique Drawing 7 is the conventional example of bearing equipment equipped with the hydrodynamic bearing. The sleeve 4 is equipped with the pars basilaris ossis occipitalis 45 which receives lower limit side 1a of a shaft 1 in this bearing equipment. In this example, the dynamic pressure slots 41

and 42 for radial support are formed in inner skin 4a of a sleeve 4, and the dynamic pressure slot 30 for axial support is formed in lower limit side 1a of a shaft 1.

This sleeve 4 is a thin cylinder to which a bore becomes large by the temperature rise. Therefore, if this sleeve is combined with the shaft with which a coefficient of thermal expansion consists of the same ingredient as this sleeve, since the amount of increases of a shaft diameter and the amount of increases of a sleeve bore by the temperature rise will become the same, even if service temperature changes, a bearing clearance does not change.

Usually, this sleeve 4 is produced with the copper alloy with good cutting ability, and the shaft 1 is produced with the martensitic stainless steel with which a comparatively high degree of hardness is obtained, in order to make a blemish hard to attach at the time of handling. Here, since a difference is in a coefficient of thermal expansion with a copper alloy and martensitic stainless steel (it is copper alloy:17x10-6-18x10-6 (1/K) and martensitic-stainless-steel:10x10-6-11x10-6 (1/K) at coefficient of linear expansion), a bearing clearance changes with change of service temperature to this bearing equipment, namely, there is a trouble that the bearing engine performance changes in it.

In order to solve this trouble, while a coefficient of thermal expansion uses the austenitic stainless steel (coefficient of linear expansion: 16x10-6 to 17x10-6 (1/K)) approximated to the copper alloy for Japan JP,10-89345,A as an ingredient of a shaft, hardening the front face of a shaft by nitriding treatment is proposed. While change of the bearing clearance according to change of service temperature hardly arises in the above-mentioned official report according to this approach,

even if it is an elasticity shaft made from austenitic stainless steel, it is indicated by it that it becomes the degree of hardness which the front face hardened by nitrification scratches and can make wear slight.

However, by the approach given in the above-mentioned official report, since nitriding treatment is performing hard facing of a shaft, a very hard chromium nitride is formed in a surface layer. Consequently, the corrosion resistance of a shaft surface falls as compared with the case where nitriding treatment is not carried out. Moreover, in connection with a low thing, the following troubles also have the corrosion resistance of a shaft surface in the hydrodynamic bearing indicated by the above-mentioned official report.

That is, since the scale and a nitride particle exist in the shaft surface by which nitriding treatment was carried out, it is necessary to remove these at a back process so that these may drop out and it may not enter into a bearing clearance. Here, as mentioned above, since the shaft surface by which nitriding treatment was carried out has low corrosion resistance, when this removal process is performed by acid cleaning, it has a possibility that a front face may corrode. In order to avoid corrosion, it is necessary to perform this removal process by the mechanical approach but, and since the mounting-stud slot is formed in the edge of a shaft, the time amount and costs of a shaft great for processing the whole surface by the mechanical approach are required after nitriding treatment.

This invention makes it a technical problem to consist of combination of the copper sleeve which is made paying attention to the trouble of such a conventional technique, and does not almost have change of the bearing clearance according to change of service temperature as bearing equipment equipped with the hydrodynamic bearing, and the shaft made from austenitic

stainless steel, and to offer what the surface hardness of a shaft is not only high, but was excellent in the corrosion resistance of a shaft.

This invention makes it a technical problem to make good deactivation endurance of bearing equipment equipped with the hydrodynamic bearing by using a shaft with high and surface hardness and the good granularity of the bearing surface again.

The indication of invention In order to solve the above-mentioned technical problem , this invention be equip with a shaft and a sleeve , a carburization hardening layer be form in a front face , and the surface hardness of the bearing surface of this shaft offer the bearing equipment characterize by to be 400 or more Hv(s) by perform carburization processing to the stem which said shaft become from the austenitic stainless steel by which solution treatment be carried out in the bearing equipment which be make to produce dynamic pressure and acquire a bearing operation among both .

The bearing surface of a shaft is a front face of the shaft which has two incomes with a sleeve and dynamic pressure produces (interaction with a sleeve), and when the part in which the dynamic pressure slot on the shaft surface is formed when the dynamic pressure slot is formed in the shaft is pointed out and the dynamic pressure slot is formed in the sleeve, it points out the part in contact with said dynamic pressure slot on the shaft surface.

As austenitic stainless steel, SUS303, SUS304, and SUS316 grade are mentioned. From the point of cutting ability, it is desirable that using SUS303 and SUS304 uses SUS316 from a corrosion resistance point.

Since there are many ferrite contents, this ferrite and carburization gas react, and the austenitic stainless steel by which solution treatment is not carried out is

M3. The deposit of C arises, corrosion resistance falls or there is a possibility that sufficient hardness may not be obtained. Since the austenitic stainless steel by which solution treatment was carried out is used as an ingredient of a shaft in this invention, it is the above M3. The deposit of C is controlled. Moreover, since not nitriding treatment but carburization processing is performing hard facing, it is hard to produce a chromium nitride in a shaft surface.

Therefore, according to this bearing equipment, the corrosion resistance of a shaft surface and sufficient hardness are secured.

As for the surface roughness (Ra) of the bearing surface of said shaft, in this bearing equipment, it is desirable that it is 0.30 micrometers or less. Thereby, the sliding endurance at the time of the deactivation of a hydrodynamic bearing becomes good.

In the bearing equipment (hydrodynamic bearing equipment equipped with a shaft, this shaft, and the sleeve that has two incomes) which the desirable gestalt of the bearing equipment of this invention is equipped with a shaft and a sleeve, is made to produce dynamic pressure among both, and acquires a bearing operation When said sleeve consists of a copper alloy and said shaft performs carburization processing to the stem which consists of austenitic stainless steel by which solution treatment was carried out A carburization hardening layer is formed in a front face, and it is characterized by carrying out impurity removal processing of the bearing surface of a shaft, and becoming surface roughness (Ra) to 0.30 micrometers or less, and surface hardness having become 400 or more Hv(s).

According to this bearing equipment, with the combination of a copper sleeve and

the shaft made from austenitic stainless steel, while there is almost no change of the bearing clearance according to change of service temperature, the sufficient hardness (400 or more Hv(s)) and the surface roughness for sliding endurance at the time of the corrosion resistance of a shaft surface and the deactivation of bearing are secured.

Said sleeve consists of martensitic stainless steel or ferritic stainless steel, and when said shaft performs carburization processing to the stem which consists of austenitic stainless steel by which solution treatment was carried out, a carburization hardening layer is formed in a front face, and in the bearing equipment which this invention is equipped with a shaft and a sleeve again, makes produce dynamic pressure among both, and acquires a bearing operation, the bearing equipment characterized by for the surface hardness of the bearing surface of this shaft to be 400 or more Hv(s) offers.

The coefficient of linear expansion of martensitic stainless steel and ferritic stainless steel is 10x10-6 to 11x10-6 (1/K), and is smaller than the coefficient of linear expansion (16x10-6 to 17x10-6 (1/K)) of austenitic stainless steel. Therefore, since a bearing clearance decreases slightly at the time of an elevated temperature, bearing equipment equipped with the shaft which consists of austenitic stainless steel, and the sleeve which consists of martensitic stainless steel or ferritic stainless steel can lessen the fall of bearing rigidity by the viscosity down of the lubricant at the time of an elevated temperature.

Carburization processing is performed under a carburization gas ambient atmosphere by heating in temperature of 400-500 degrees C for 10 to 50 hours. As gas for carburization, the mixed gas of CO and H2, the mixed gas of RX gas (mixed gas of CO:23% and CO21%, H2:31%, H2O:31%, and the remainder N2)

and CO2 gas, etc. can be used.

However, under the ambient atmosphere which contains CO at 400-500 degrees C, since oxidation (4CO+3Fe->4 CO+Fe 3O4) of Fe is also produced in carburization (2 C->CO2+C) and coincidence, an iron system internal oxidation layer is formed in a 2-3-micrometer part from a front face, and a front face becomes black. Therefore, it is desirable to perform pickling processing in order to remove impurities, such as an iron system internal oxidation layer or soot, after carburization processing. Moreover, it is desirable to perform finish grinding and barrel finishing (impurity removal processing) so that the granularity (Ra) of the bearing surface of a shaft in contact with a partner sleeve may be set to 0.30 micrometers or less. A surface impurity (scale) is also removed by this barrel finishing. In addition, if the granularity (Ra) of the bearing surface of a shaft exceeds 0.30 micrometers, the deactivation endurance of bearing will fall.

On the other hand, when unsaturated hydrocarbon gas, for example, acetylene, and ethylene are used as carburization gas and carburization down stream processing is performed under the vacuum of 1 or less Torr, since the carburization hardening layer which said iron system internal oxidation layer hardly produces is formed, it is desirable. Moreover, by this approach, since Cr23C6 cannot deposit easily in a carburization layer, a corrosion resistance very high carburization hardening layer is formed. However, if carburization processing temperature exceeds 500 degrees C, the deposit of Cr23C6 will come to arise and corrosion resistance will fall. Moreover, processing takes time amount as carburization processing temperature is less than 400 degrees C. When these points are taken into consideration, as for carburization processing

temperature, it is desirable to consider as 400-500 degrees C.

Moreover, it is desirable to perform the process which carries out heating maintenance under a fluorine system gas ambient atmosphere before carburization processing. As for the process which carries out heating maintenance under a fluorine system gas ambient atmosphere, it is desirable to carry out on the heating temperature of 250-450 degrees C and the conditions of 10 minutes - a holding-time 1 hour. As fluorine gas to be used, the fluorine compound gas of NF3, BF3, CF4, HF, SF6, C2F6, WF6, CHF3 and SiF4, and ClF3 grade is mentioned. Although these gas may be used independently, it is usually diluted and used to about 1 - 10% with inert gas, such as N2 gas. Among these, it is a gas in ordinary temperature, and NF3 has high chemical stability, and since handling is easy, it is the most practical [NF].

In the bearing equipment of the above thing to this invention, after said shaft is held under a fluorine system gas ambient atmosphere for 10 minutes to 1 hour at 250-450 degrees C, it is desirable [a shaft] under the ambient atmosphere of unsaturated hydrocarbon gas, and the vacuum of 1 or less Torr that a carburization hardening layer is formed in a front face by performing carburization processing at the temperature of 400-500 degrees C.

The best gestalt for inventing The operation gestalt of this invention is explained hereafter.

Drawing 1 is the outline sectional view showing the slewing gear with which the bearing equipment equivalent to 1 operation gestalt of this invention was applied.

This slewing gear is a spindle motor for magnetic disk drives, the lower part of a shaft 1 is fixed to the base 2, and the upper part of this shaft 1 is arranged in the

sleeve 4 inner-**(ed) by the hub 3. The dynamic pressure slots 41 and 42 for radial support are formed in the inner skin of a sleeve 4. The receptacle side 43 of the thrust plate 5 fixed to the shaft 1 is formed in the upper part of a sleeve 4. The dynamic pressure slot 30 for axial support is formed in the vertical side of a thrust plate 5. The bearing surface of this shaft 1 is a part which contacts the dynamic pressure slots 41 and 42 among the front faces of a shaft.

The upper part of this sleeve 4 is closed by the cover plate 6. The through hole 61 into which a shaft 1 fits loosely is formed in this cover plate 6, and the upper limit section of a shaft 1 is projected above this through hole 61. Rota 7 is being fixed to the inner skin of the lower part of a hub 3, and the stator 8 which counters this is being fixed to the upper part of the base 2.

A sleeve 4 and a thrust plate 5 have good cutting ability, and formation of the dynamic pressure slot by plastic working (coining) is produced with the easy copper alloy. After a shaft 1 forms the austenitic stainless steel by which solution treatment was carried out in the shape of a shaft, a carburization hardening layer is formed in a front face by performing carburization processing to this. In for the disks made from aluminum, in for glass disks, the thing made from ferritic stainless steel is used for a hub 3 for the thing made from an aluminium alloy.

Therefore, the spindle motor of this operation gestalt is equipped with bearing equipment equipped with the shaft 2 equivalent to 1 operation gestalt of this invention, and the sleeve 4. Therefore, there is not only almost no change of the bearing clearance according to change of service temperature, but the corrosion resistance of a shaft surface and sufficient hardness are secured to this bearing equipment. Consequently, the spindle motor of this operation gestalt becomes

what has high dependability and endurance.

[A quality evaluation trial of a shaft]

In order to explain concretely the engine performance of the shaft which constitutes the bearing equipment of this invention, the quality evaluation trial of the shaft using a test piece as shown below was performed.

The ingredient and the heat treatment approach of each test piece are shown in the following table 1. As a test piece, what processed the solution treatment article (solution-treatment conditions: 1050 degrees C after 1-hour heating, water cooling.) of austenitic stainless steel with a die length of 50mm in the shape of a rod for the diameter of 5mm was used by No.a-1-a-5 and No.b-1-b-4. In No.b-5 and b-6, what processed martensitic stainless steel in the shape of [as the above / same] a rod was used.

About No.a-1-a-3, carburization processing was performed, after performing first the process which carries out heating maintenance under a fluorine system gas ambient atmosphere to a test piece. That is, first, the test piece was put in in the furnace, the mixed gas (10% of NF3 concentration) of nitrogen and nitrogen fluoride (NF3) was introduced in this furnace, and heating maintenance was carried out for 20 - 30 minutes at the temperature of 300-380 degrees C. Next, this test piece was put in in the furnace under the mixed-gas ambient atmosphere of RX and CO2, and carburization processing was performed by carrying out heating maintenance at the temperature of 450-500 degrees C for 40 hours. Thereby, the thickness of the hardening layer formed of carburization processing is set to about 20-30 micrometers.

About No.a-4 and a-5, the process which carries out heating maintenance under a fluorine system gas ambient atmosphere to a test piece was first performed like

the above. Next, carburization processing was performed by putting in this test piece in the furnace under an acetylene ambient atmosphere, making the inside of this furnace into the bottom of the vacuum of 1 - 30x10-2Torr, and carrying out heating maintenance at the temperature of 450-500 degrees C for 40 hours. Thereby, the thickness of the hardening layer formed of carburization processing is set to about 20-30 micrometers.

About No.b-1-b-3, the process which carries out heating maintenance under a fluorine system gas ambient atmosphere to a test piece was first performed like the above. Next, this test piece was put in in the furnace under an ammonia gas ambient atmosphere, and nitriding treatment was performed by carrying out heating maintenance at the temperature of 400-450 degrees C for 48 hours. Thereby, the thickness of the hardening layer formed of nitriding treatment is set to about 20-30 micrometers.

About No.b-4, it used as it is, without performing heat treatment to a test piece.

About No.b-5 and b-6, what carried out oil-quenching after holding for 30 minutes at 950 degrees C and 1050 degrees C, respectively, and carried out tempering at 160-180 degrees C for 2 hours was used.

The dimensional change before and behind surface hardness, surface roughness, and heat treatment (the amount of expansion) was measured about the test piece of No.a-1-a-5 and No.b-1-b-6 with which these processings were performed. Moreover, pickling processing immersed in an HF-HNO3 mixing acid was performed, and the condition of the test piece after processing was investigated. These results are collectively shown in the following table 1. The result of pickling processing observes an appearance and shows the case where are "O", the elution of a base material produced what has a very good appearance, and an

appearance is spoiled remarkably, by "x."

As for the dimensional change before and behind surface roughness and heat treatment, No.a-1-a-5 are smaller, although No.b-1-b-3 are harder in the comparison with No.a-1-a-5 by which the front face is hardened by carburization processing, and No.b-1-b-3 by which the front face is hardened by nitriding treatment as for surface hardness as shown in Table 1. Therefore, No.a-1-a-5 are more advantageous in respect of post-processing nature. Moreover, although all No.a-1-a-5 are O for the result of pickling processing, all No.b-1-b-3 are x and it turns out that the direction of No.a-1-a-5 is excellent in corrosion resistance and the handling nature on manufacture.

About the condition of the test piece after heat treatment, by No.b-1-b-3, the scale, the nitride particle, and the soot-like deposit existed in the front face, and the front face was black. In No.a-1-a-3, the soot-like deposit existed in the internal oxidation layer and the front face, and the front face was black. In No.a-4 and a-5, an internal oxidation layer was hardly observed.

Pickling processing is performed in order to remove such an internal oxidation layer and a surface deposit, but since the elution of a remarkable base material arises in this pickling processing, No.b-1-b-3 can remove completely neither an internal oxidation layer nor a surface deposit. On the other hand, in No.a-1-a-5, since the elution of a base material hardly arises in pickling processing, an internal oxidation layer and a surface deposit are completely removable.

The graph of drawing 2 shows the result of having carried out the X diffraction of the front face of a-No.4 test piece before pickling processing. From this graph, only the peak of the austenitic stainless steel which is a base material is observed. That is, carbon is the concentration below the solid-solution limit of an austenite,

and is dissolving completely in an austenite. The graph of drawing 3 shows the result of having carried out the X diffraction of the front face of b-No.2 test piece before pickling processing. The peak of the austenitic stainless steel which is a base material from this graph is not observed at all, but the peak of chromium nitrides, such as 2 (Cr, Fe) Ns (1-X) and Cr2N, is observed.

The photograph of drawing 4 shows the cross section by the side of the front face of a-No.4 test piece before pickling processing. The photograph of drawing 5 shows the cross section by the side of the front face of b-No.2 test piece before pickling processing. With the photograph of drawing 5 , the front face is very coarse and, in addition to the boundary of a compound layer and a base material being known clearly, a crack etc. is observed. On the other hand, with the photograph of drawing 4 , a front face is gently-sloping and the boundary line of a compound layer and a base material is not accepted, either.

Although a sludge is not generated by carburization processing from these results at the front-face side of a-No.4 test piece, it turns out that the compound layer which consists of a chromium nitride by nitriding treatment is formed in the front-face side of b-No.2 test piece.

in addition, No.b- which consists of martensitic stainless steel as shown in Table 1 -- 5 and 6 have a high degree of hardness. On the other hand, although it consists of austenitic stainless steel by which solution treatment was carried out, since heat treatment is not carried out, a degree of hardness is low [No.b-4]. Therefore, with the configuration of No.b-4, it turns out that there is a possibility that a blemish etc. may arise, at the time of the handling in a processing process.

Next, about the test piece of No.b-4-b-6, finish-machining by grinding was performed as it was without performing pickling processing after performing the

above-mentioned heat treatment and pickling processing about No.a-1-a-5, and performing the above-mentioned heat treatment about the test piece of No.b-1-b-3. About each test piece after this processing, it is JIS. Z The salt spray test was performed for 2 hours based on 2371. Moreover, after preparing as No.b-7 what processed the annealing article (with no solution treatment) of SUS303 in the shape of [as other test pieces / same] a rod and performing the same heat treatment as No.a-1-a-3, and pickling processing to this, finish-machining by the same grinding was performed and the salt spray test was performed on the same conditions.

The result is shown in the following table 2. "x" shows the case where rust produces remarkably the case where rust produces slightly the case where rust does not arise at all, in "O" in "**."

Although rust did not arise at all by the salt spray test in No.a-1-a-5 which used the solution treatment article among No.a-1-a-5 by which the same heat treatment (carburization processing) and pickling processing were made, and b-7 as shown in Table 2, in No.b-7 which used the annealing article which is not a solution treatment article, rust had arisen slightly. Moreover, in No.b-1-b-3 by which nitriding treatment was carried out, rust arose remarkably. No. to which heat treatment is not carried out -- No.b- which consists of martensitic stainless steel although rust did not arise in No.b-4 which consist of austenitic stainless steel among b-4 to b-6 -- in 5 and 6, rust arose remarkably.

The graph of drawing 6 shows the result of having carried out the X diffraction of the front face of b-No.7 test piece before pickling processing. From this graph, peaks, such as 3(Cr, Fe) C and alpha-Fe, are observed in addition to the peak of the austenitic stainless steel which is a base material. If a solution treatment

article is not used from this result even if it is austenitic stainless steel, it turns out that the reaction of a ferrite and carburization gas arises at the time of carburization processing, and 3(Cr, Fe) C deposits.

The bearing equipment equipped with the shaft equivalent to test piece No.a-1-a-5 and the sleeve made from a copper alloy from the above result not only does not almost have change of the bearing clearance according to change of service temperature, but since the corrosion resistance of a shaft surface and sufficient hardness are secured, it turns out that the dependability and endurance of equipment will become high. Since especially bearing equipment equipped with test piece No.a-4 to which vacuum carburization was performed, and the shaft acquired like a-5 can skip pickling down stream processing of a shaft, it has the effectiveness which can lessen the number of routings.

In addition, in the above-mentioned example, although the sleeve was made into the product made from a copper alloy, as a bearing clearance decreases slightly at the time of an elevated temperature, the fall of bearing rigidity by the viscosity down of the lubricant at the time of an elevated temperature can also be lessened by using the sleeve which consists of martensitic stainless steel or ferritic stainless steel. That is, the fall of bearing rigidity at the time of an elevated temperature can also be further lessened using the austenitic stainless steel by which made the sleeve and the hub the product made from ferritic stainless steel by one, and solution treatment was carried out to the shaft instead of using a copper alloy for a sleeve.

[A temperature characteristic trial and deactivation durability test] of bearing equipment

First, the 0 degree C torque when considering as the combination which shows

the combination of a shaft and a sleeve in the following table 3 about the slewing gear of drawing 1 , and 80-degree C load-carrying capacity were calculated by count. These values are computed by substituting the coefficient of linear expansion of a shaft and a sleeve, a shaft diameter, bearing width of face, rotational speed, and the viscosity of a lubricating oil for a predetermined formula.

The diameter of a shaft was set to 6mm and bearing width of face (dimension of the shaft orientations of both the dynamic pressure slots 41 and 42) was set to 6mm. The lubricating oil was made into the diester oil and rotational speed was set to 7200rpm.

Although the coefficient of linear expansion of C5191 (phosphor bronze), SUS303, and SUS304 was 17 to 18x10-6 (1/K), the coefficient of linear expansion of SUS316 was 16 to 17x10-6 (1/K) and SUS420J, SUS440C, and the coefficient of linear expansion of SUS430F (ferritic stainless steel) were ten to 11x10-6 (1/K), the following numeric values were used in this count. C5191 (phosphor bronze), SUS303, and SUS 304:17.3x10-6 (1/K). SUS 316:16.0x106 (1/K). SUS420J, SUS440C, and SUS430F(ferritic stainless steel):10.3x10-6 (1/K).

From the acquired value, the ratio of 80 degrees C [to the torque value in 0 degree C] load-carrying capacity was computed for every sample. and -- each -- the relative value when setting the ratio of No.28 to 1 was computed as a temperature characteristic value about the ratio. It is shown that the temperature characteristic of bearing equipment is so good that this value is large. This result is also shown in Table 3.

Next, the slewing gear of drawing 1 was assembled in the combination of the

shaft and sleeve which are shown in Table 3. The diameter of a shaft is 6mm and bearing width of face (dimension of the shaft orientations of both the dynamic pressure slots 41 and 42) is 6mm.

The shaft of No.21, and 22 and 26 performed and produced the same processing as a-3 using the solution treatment article of same SUS303 as the above-mentioned a-3. The shaft of No.23 performed and produced the same processing as a-1 using the solution treatment article of same SUS304 as the above-mentioned a-1. No. -- 24 or 25 shafts performed and produced the same processing as a-5 using the solution treatment article of same SUS316 as the above-mentioned a-5.

The shaft of No.27 was used as it was like b-4 using the solution treatment article of same SUS303 as the above-mentioned b-4, without heat-treating. The shaft of No.28 performed and produced the same processing as b-5 using the SUS420J2 [same] as the above-mentioned b-5. The shaft of No.29 performed and produced the same processing as b-6 using the same SUS440C as the above-mentioned b-6.

This slewing gear was placed sideways and deactivation of this slewing gear was carried out 300,000 times on condition that radial road:1N and rotational-speed:7200rpm, using a diester oil as a lubricating oil. After this trial, the faulted condition by wear was observed about the dynamic pressure generating slot on the sleeve, and the bearing surface of a shaft using the stereoscopic microscope. This observation result is also shown in Table 3. In Table 3, it is shown that, as for "O", damage had hardly produced that damage extent of "x" was remarkably large.

As shown in Table 3, a shaft is [a sleeve] a product made from a copper alloy in

the product made from austenitic stainless steel, and the coefficient of thermal expansion of a shaft and a sleeve is almost the same at No.21, and 23, 24, 26 and 27. A shaft is [a sleeve] a product made from ferritic stainless steel in the product made from austenitic stainless steel as No.22, and the coefficient of thermal expansion of a sleeve is smaller than the coefficient of thermal expansion of a shaft at 25. A shaft is [a sleeve] a product made from a copper alloy in the product made from martensitic stainless steel as No.28, and the coefficient of thermal expansion of a sleeve is larger than the coefficient of thermal expansion of a shaft at 29.

A temperature characteristic value has the coefficient of thermal expansion of a sleeve largest than the coefficient of thermal expansion of a shaft in small combination (22 No. 25), and becomes small in order of [coefficient of thermal expansion / of a shaft, and the combination (No.21, 23, 24, 26, 27) with the almost same coefficient of thermal expansion of a sleeve and a shaft] combination (28 No. 29) with the large coefficient of thermal expansion of a sleeve so that the result of Table 3 may show.

That is, although the fall of bearing rigidity accompanying the viscosity down of a lubricating oil arises at the time of an elevated temperature, since a bearing clearance becomes small in connection with a temperature rise in combination (22 No. 25) with the small coefficient of thermal expansion of a sleeve rather than the coefficient of thermal expansion of a shaft, the bearing rigidity at the time of an elevated temperature is improvable. On the other hand, since a bearing clearance becomes large in connection with a temperature rise in combination (No. 28 and 29) with the large coefficient of thermal expansion of a sleeve rather than the coefficient of thermal expansion of a shaft, bearing rigidity falls greatly

at the time of an elevated temperature.

About deactivation endurance, the good result was obtained by No.21-25 whose surface roughness (Ra) the surface hardness of a shaft is 400 or more Hv(s), and is 0.30 micrometers or less, and 28 and 29. On the other hand, as for deactivation endurance, No.26 whose surface hardness of a shaft is less than 200 Hv, very low No.27, and the value to which surface roughness (Ra) exceeded 0.30 micrometers were insufficient.

Availability on industry As explained above, while a copper alloy and a coefficient of thermal expansion make a shaft the almost equal product made from austenitic stainless steel, according to the bearing equipment of this invention, the corrosion resistance of a shaft surface and sufficient hardness are secured.

Moreover, according to this invention, according to the surface hardness of a shaft being high and the granularity of the bearing surface of a shaft being good, while excelling in the deactivation endurance of bearing, bearing equipment excellent also in the corrosion resistance of a shaft is obtained.

Moreover, since there is not only almost no change of the bearing clearance according to change of service temperature by specifying the ingredient and the hard facing approach of a shaft which are combined with the sleeve which consists of a copper alloy, but the corrosion resistance of a shaft surface and sufficient hardness are secured according to the bearing equipment of this invention, the dependability and endurance of equipment will become high.

Moreover, according to the bearing equipment of this invention, the bearing rigidity at the time of an elevated temperature is improvable by considering as

combination with the coefficient of thermal expansion of a sleeve smaller than the coefficient of thermal expansion of a shaft.

[Brief Description of the Drawings]

Drawing 1 is the outline sectional view showing the slewing gear with which the bearing equipment equivalent to 1 operation gestalt of this invention was applied.

Drawing 2 is a graph which shows the result of having carried out the X diffraction of the front face of a-No.4 test piece before pickling processing in an example.

Drawing 3 is a graph which shows the result of having carried out the X diffraction of the front face of b-No.2 test piece before pickling processing in an example.

Drawing 4 is a photograph in which the metal texture of the cross section by the side of the front face of a-No.4 test piece before pickling processing is shown in an example.

Drawing 5 is a photograph in which the metal texture of the cross section by the side of the front face of b-No.2 test piece before pickling processing is shown in an example.

Drawing 6 is a graph which shows the result of having carried out the X diffraction of the front face of b-No.7 test piece before pickling processing in an example.

Drawing 7 is the outline sectional view showing an example of conventional bearing equipment.